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Abstract

POINT REACTOR KINETICS AND STABILITY CRITERIA

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The purposes of this paper are: (a) to examine the form of point reactor kinetics equations that might be used for the correlation of severe transient experimental data; (b) to review existing stability criteria and to discuss some practical aspects of nonlinear reactor stability.

To this end, the point kinetics equations derived by different authors from fundamental transport theory are reviewed and reinterpreted. It is observed that these equations include terms that depend on the rate of change of the shape of the neutron density distribution throughout the reactor core. This rate of change may become appreciable even when the shape changes are relatively small but occur over a short period of time. It is concluded that shape changes should be considered when correlating severe transient experimental data. In support of this conclusion, some numerical results are presented.

Other conclusions that may be derived from the reinterpretation of the kinetics equations are:

a. Reactivity is an ultimately bounded function as it should be since there is only a limited number of neutrons per fission.

b. Conclusion (b) suggests that no reactor can admit a finite escape time unless fuel is injected at an infinite rate.

c. Point kinetics equations can always be used to answer questions of ultimate stability or instability.

Next, stability criteria for nuclear reactors are discussed. It is observed that necessary and sufficient conditions for stability with respect to small perturbations are well established both theoretically and experimentally. It is also noted, however, that instability with respect to small perturbations does not necessarily constitute a safety hazard. Examples of bounded oscillations are given.

Regarding nonlinear stability, it is observed that most of the derived sufficient criteria for reactor stability pertain to global asymptotic stability and they are very conservative. It is suggested that less restrictive conditions for stability might be established by including in the analysis some practical limitations. Specifically:

a. Analytical approximations for feedback reactivity should be functions that are ultimately bounded.

b. The analysis should include delayed neutrons since stability requirements derived without delayed neutrons may be so conservative as to be of no practical importance.

c. Stability criteria should be derived for a limited range of operating power levels and/or reactivity inputs since no reactor can be built to withstand an infinite power or energy storage.

Admittedly, the inclusion of these practical aspects in the analysis renders the problem of stability more involved but the results are more meaningful. This important point is illustrated by means of some practical examples.